Force Propagation and Friction in Granular materials

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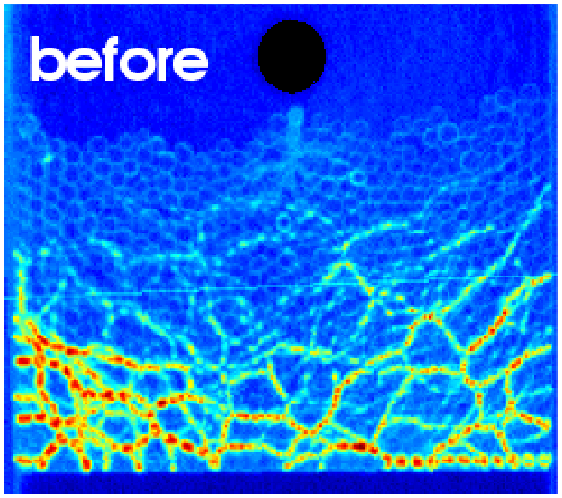
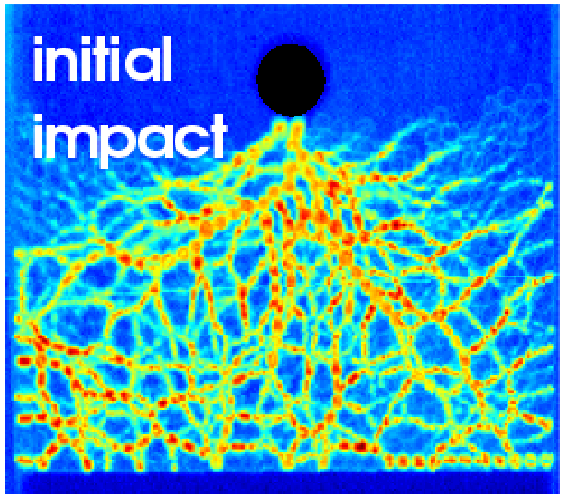
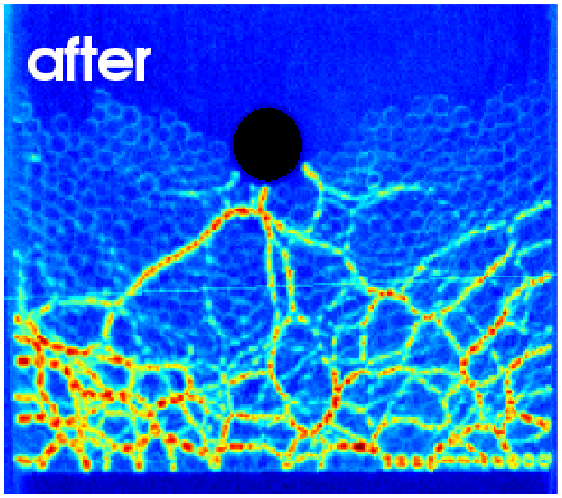
Force transmission in static granular materials

- The way in which forces are transmitted in dense granular materials is a subject of heated scientific debate. In recent measurements (Physica D **182**, 274 (2003)) we have addressed this problem through novel photoelastic studies which have yielded experimental results for the Green's function in response to a locally applied force. We have shown that the nature of force transmission depends crucially on the amount of order/disorder associated with the packing. For instance, for strong disorder, we see an elastic-like response. For ordered systems, both elastic and wave-like responses are possible, and ongoing work will address the relevance of each scenario. Using the same photoelastic techniques, we have carried out initial studies of the effect of an impact (e.g. a meteor) on a granular surface. This work (images below) is being carried out by ***undergrad, Joyce Coppock, and post-doc, Karen Daniels.***





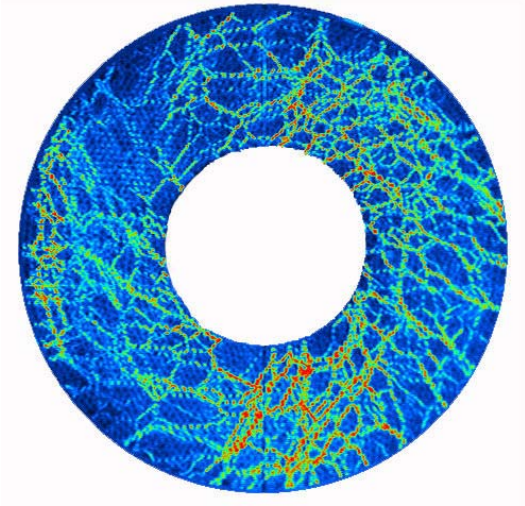


The way that a granular material supports forces is a very challenging and unsolved problem. This is also far from an academic issue, as witnessed by recent problems experienced by Martian rovers, some of which (e.g. the Beagle) may have become permanently bogged down in a crater. And many industrial problems require this type of information. There is currently an intense debate within the granular materials research community about the right models to describe this situation. We have carried out tests of these models by applying small point forces on specially created two-dimensional granular models that use a powerful technique, photoelasticity, to reveal the forces on each particle These studies have been able to reduce the number of possible models. Additional work is directed towards a complete answer. We also use the same technique to visualize the forces of an impacting object on a granular surface (e.g. a meteorite striking the surface of the earth or moon). The images on this page show frames from a high-speed video of this process. We have been using this system as a research opportunity for undergraduate students. In particular, Ms. Joyce Coppak has carried out independent studies as part of her undergraduate work at Duke. In addition, Mr. Andy Lane, worked on this project as a high school student last year. We also are embarking on a rigorous scientific study of such impacts.

Education/Training: Work on force tranmission/Green's functions has been carried out by **Junfei Geng**, who has also carried out experiments to characterize diffusion and mobility in dense granular materials, and the role of preparation history on granular structures, such as heaps. Dr. Geng successfully defended his Ph.D. thesis in August, 2003, and is now employed by an economic market forcasting company. Work in on this project is now being carried out by **Trush Majmudar, Brian Tighe John Wambaugh, and Peidong Yu** (all Ph.D. candidates) and **Dr. Brian Utter** (post-doc). **Post-docs Karen Daniels and Jean-Philippe Matas** carry out closely related work.. Two undergrads, **John Helms and David Marks**, (picture at right) are involved in novel projects this summer. John will test a model of granular friction that pertains to earthquake phenomena, and David will explore tests of Edwards entropy concepts.

Outreach: Several very recent outreach activities have been 1) a series of three student-directed lectures at the Physbio NATO Summer School program *From Pattern Formation to Granular Physics and Soft Condensed Matter*, and 2) a similar series of six lectures at the Isaac Newton Institute-University of Cambridge Programme on *Granular and Particle-Laden Flows*.

Top: David Marks prepares an Experimental test of Edwards entropy; Bottom: force chains in a Couette Shear exerperiment



Additional Community Contributions: The PI's are part of the organizing committee for the international meeting, Dynamics Days. The PI is a member of the organizing committee for Powders and Grains, 2005, and for the NATO summer school above. The PI is past-chair and the co-PI is an excecutive committee member of the APS Group on Statistical and Nonlinear Physics. The PI is also editor or has editorial responsibilities for the journals *Physics of Fluids, Granular Matter, Physica D, and SIADS.*

In general, our group has a significant focus on understanding the physics of granular materials. The issues at hand are both intellectually challenging and of great practical importance. Granular handling devices fail much much more often than devices for more conventional materials (e.g. fluid handling devices). And, enormous amounts of resources from coal to grains to pharmaceutical powders, and of course in dollars, are involved. One study has suggested that as much as 1 $Trillion a year is spent on granular materials each year in the US alone. Thus, advances in our understanding in this area can be truly significant in the long term for the country. NSF supported work at Duke is on the cutting edge of progress here. In addition, students have significant opportunities for training in scientific research.